EDDY GENERATION PROCESSES ASSOCIATED WITH ISLANDS

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LONG-TERM GOAL

My long term goal is to contribute to our understanding of the dynamics of the formation of eddies in the lee of oceanic islands, and their influence on primary productivity. Of particular interest to me are to quantify the relative importance of instability of the large scale currents, and local variations of the wind-stress curl, in exciting mesoscale eddies.

SCIENTIFIC OBJECTIVES

We proposed to investigate the influence of islands and island chains on mesoscale current variability and ocean circulation. The study is focussed on understanding the relative significance of the mechanisms which give birth to mesoscale eddies: local wind-driven processes across the flanks and in the lee of islands, and dynamic instabilities of impinging mean currents. Additionally, we are examining the propagation and impact of the island-associated eddies on the mean currents leeward of an island or island chain. The study is based on existing observations and numerical experimentation.

APPROACH

We have first synthesized prior observations of mesoscale currents and air-sea interactions collected around the Hawaiian Islands. Several complementary data sets were used: wind data from NCAR aircraft flights, ERS-1 scatterometer measurements, a 6-year uninterrupted time series of AVHRR sea surface temperature images, WOCE-SVP drifting buoy tracks, ADCP and CTD transects taken during ship transit to/from Honolulu.

We will then use the Semi-spectral Primitive Equation Model (SPEM) and its descendents, to examine island-associated eddy generation. We will consider the two forcing hypotheses in isolation and together, in

geometrical settings ranging from the highly-idealized to the complex. In each case, observed eddy statistics will be compared with statistics from the model, with the model forcing constrained and guided by the observations.

WORK COMPLETED

We have completed in 1997 the analysis of the observations of anticyclonic eddies. Work on the cyclonic eddies is progressing, and we have begun analyzing the ERS and NSCAT wind fields in the lee of the islands to further quantify the role of Ekman pumping. We have made contact with Haidvogel's group and have discussed with them the use of their model for our application. We plan to shift our effort to modeling in Summer of 1998.

RESULTS

We have established that anticyclonic eddies are principally driven by the instability of the mean flow, Ekman pumping playing a secondary role. These results have been submitted to Nature; the text of the Nature abstract follows.

"Period doubling, vortex pairing and eddy rectification in an unstable anticyclonic shear flow in the ocean", by Flament, Lumpkin, Tournadre, Kloosterziel, and Armi.

Abstract: "Transition to subharmonic frequencies is an ubiquitous characteristic of non-linear systems, and, in particular, of many inherently non-linear fluid flows. The archetype of such flows is the turbulent free shear layer. For large Reynolds numbers, it is dominated by large two-dimensional coherent vortices, which, as the flow evolves downstream, successively merge in pairs, increasing the width of the layer. Here, we present new observations of the downstream evolution of a vortex sheet in an oceanic setting, formed as the North Equatorial Current passes the island of Hawai'i. We will show that finite amplitude anticyclonic vortices result from instability of the shear, and that the initial orbital period of the vortices is 3 days (one pendulum day at this latitude), centrifugal instability presumably inhibiting further spin up of the vortices. While advected downstream, the vortices pair and merge into successively larger vortices, in a geometric sequence of longer orbital periods. Vortices from the first two subharmonic transitions (6 and 12 days) are rectified into a narrow islandward counter current, accelerated by convergence of the mean meridional flux of zonal momentum. This previously unknown current, which we name the Hawai'i Lee Counter Current (HLCC), extends zonally

over 1000 km, has a width of 50 km, and a speed of 8 cm/s."

Two more papers, which will be part of graduate student Rick Lumpkin's dissertation, are nearing completion (expected submissions: 02/98 and 12/97), one expanding on the Nature paper, one discussing vortex merging and clarifying some conceptual problems that we discovered in the published literature.

IMPACT/APPLICATION

The processes studied in this project correspond to strong vertical water motions, through upwelling (cyclonic) or downwelling (anticyclonic), and therefore affect the flux of nutrients into the euphotic layer. By quantifying the dynamics of these processes, we provide a general framework for interpreting biological and biochemical observations in the lee of oceanic islands.

Many current and future military operations take place in the proximity of islands. Since the processes studied in this project have been identified in a variety of other geographical settings (Canary, Socotra, Crete, Corsica, Madeira to name a few), understanding them is critical in order to tune models used for operational applications.

TRANSITIONS

We have issued a poster distributed to marine professionals and to the public schools in Hawaii, outlining in plain language the different oceanographic process affecting the marine environment around Hawaii, and in particular the lee eddies. This poster has been well received, especially by the fishermen who have known for a long time the existence of the lee eddies and their influence on their catch.

RELATED PROJECTS

Below I list work ongoing work funded by other agencies, complementary to this project:

- "Satellite remote sensing studies of biological and biogeochemical processes in the ocean" (NASA, Bidigare and Flament). In this ongoing project, we will look at the impact of lee eddies on ocean color, using SeaWifs images.

- "Acquisition and operation of an array of high frequency Doppler radars for observing surface currents in Hawai'i coastal waters" (NSF-MRI, Flament, Firing, Hacker, Luther and Merrifield). In this

ongoing project, we will use recently acquired CODARs to look at the near-field evolution of the vortex sheet as it detaches the South Point of Hawaii.

- "Analysis of a 5-year series of sea surface temperature images around Hawai'i" (NOAA Sea Grant, Flament). This ongoing project is funding the systematic reprocessing of AVHRR images collected since 1990, which will be used in support of our analysis of cyclonic eddies.

- "A multi-sensor study of convergent fronts in the North Pacific" (NASA, Flament). This ongoing project is funding the processing and analysis of RADARSAT SAR images of shear lines and lee eddies.

- "Physical characteristics of the environment influencing pelagic fishes" (NOAA-NMFS). This terminating project funded the purchase and deployment of 70 ARGOS-tracked drifters deployed in the lee of the islands, the data from which was used in our Nature paper.

REFERENCES

P. Flament, C. Lumpkin, J. Tournadre, R. Kloosterziel, L. Armi, "Period doubling and vortex pairing in an anticylonic shear flow in the ocean", submitted to Nature, (November 1997)

R. Lumpkin and P. Flament, "Mean flow and eddy statistics in the lee of the Hawaiian islands", to be submitted to J. Phys. Ocean., (February 1998)

R. Lumpkin, P. Flament and L. Armi, "Vortex merging on an f-plane revisited", to be submitted to J. Phys. Ocean., (December 1997).

www: due to Nature pre-publication embargo, we cannot release on the web at this stage.